§5. Study on the Plasma Confinement Based on MHD-Transport Model

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Tearing mode instability in the presence of microscopic turbulence is investigated. The effects of microscopic turbulence on tearing mode are taken as drags which are calculated by one-point renormalization method and mean-field approximation. These effects are reduced to effective diffusivities in reduced MHD equation[1]. The renormalized equations are given by

$$\frac{\partial}{\partial t}\nabla_\perp^2\phi = -\nabla_{/\!/}\nabla_\perp^2 A - ik_\theta \frac{dj_0}{dr}A - ik_\theta gp + (\mu_c + \mu_N)\nabla_\perp^4\phi \quad (1)$$

$$\frac{\partial}{\partial t}A = -\nabla_{/\!/}\phi + (\eta_c + \eta_N)\nabla_\perp^2 A \quad (2)$$

$$\frac{\partial}{\partial t}p = ik_\theta h\frac{dp_0}{dr}\phi + (\chi_c + \chi_N)\nabla_\perp^2 p \quad (3)$$

where $h = \beta_0 / 2\varepsilon$, β_0 is the plasma beta, $\varepsilon = a / R$ is the inverse aspect ratio, k_θ is the poloidal wave number, g is the effective curvature due to the magnetic field. $\{\mu_c, \eta_c, \chi_c\}$ are the collisional ion viscosity, resistivity and thermal conductivity, respectively. $\{\mu_N, \eta_N, \chi_N\}$ are the renormalized viscosity, resistivity and thermal conductivity which are represented by the wave number and amplitude of microscopic background turbulence. In a strong turbulence limit, these coefficients are proportional to the microscopic turbulence level. Considering the short wave length mode as a background turbulence and assuming the mode is well localized around the mode rational surface, i.e., $k'_{/\!/} \to 0$, then the following relation is obtained for these coefficients,

$$\mu_N : \eta_N : \chi_N \sim \frac{1}{3} : 1 : 1 \quad (4)$$

In this limit, the electromagnetic terms with A_k vanish and the electrostatic terms with ϕ_k survive in renormalized viscosities.

The stability of tearing mode immersed in the microscopic turbulence is numerically analyzed using the model equations. $m = 2 / n = 1$ tearing mode is examined in this study, where m is poloidal mode number, n is toroidal mode number. To neglect toroidal effect, approximation $g = 2\cos\theta \to 2$ is used. (Minor radius $a = 0.4m$, major radius $R = 1.2m$, toroidal magnetic field $B = 1T$.) Collisional diffusivities are given as $\mu_c = 4.27 \times 10^{-9}$, $\eta_c = 4.1 \times 10^{-8}$, $\chi_c = 1.6 \times 10^{-9}$. The safety factor $q(r)$ is chosen as $q(0) = 1.38$ at the center and $q(a) = 4$ in the edge. The rational surface of $m = 2 / n = 1$ mode is located at $r = 0.7$. Equilibrium pressure profile is choosen as $p(r) = (1 - r^2)^2$. Equilibrium current profile is determined by q profile.

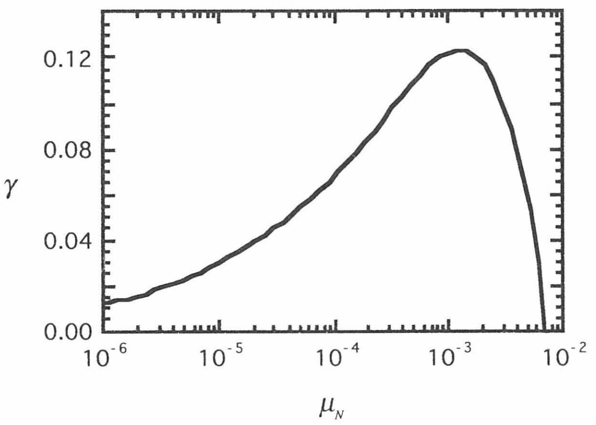

Fig.1 the dependence of growth rate on renormalized ion viscosity.

Figure 1 shows the growth rate of tearing mode on turbulent diffusivity μ_N which satisfies the relation eq. (4). This result shows that a finite amplitude of microscopic turbulence enhances the growth rate of tearing mode. For the typical parameters, we see that $\mu_N \sim 1m^2 / s$ corresponds to the growth rate $\gamma \sim (10\mu s)^{-1}$. The nonlinear growth rate is found much larger than the linear growth rate of tearing mode destabilized by collisional resistivity. This time scale is almost the same order as ones observed in various types of collapse phenomena.

In this analysis, the diagonal elements of transport matrix are kept as the turbulent effect. Inclusion of off-diagonal elements into the model and the analysis of the effect on global MHD mode are left as a future work.

Reference

1) Itoh, K., Itoh, S.-I., et al. Plasma Phys. Control. Fusion **36** (1994)279.